

Method and Device to Bend and Reshape Profiles through Roll or Matrix Bending

The present invention pertains to a method and a device to bend and reshape profiles through roll or matrix bending according to the preamble of patent claim 1. The prior art in this regard is the bending or reshaping the profile to be bent or reshaped using one or more bending tool.

The term "reshape" is understood to mean that a profile is produced from a straight panel section through a reshaping process, for example. The method according to the invention proposes novel solution approaches for this.

The term "bending" is understood to mean that profiles that have already been finished are bent in an arbitrary manner in two or three dimensions.

The term "roll bending" is understood to mean that the bending or reshaping process occurs by passing the panel section or profile to be reshaped or bent through a roll bending process. Such a roll bending machine consists essentially of a center shaping roll that lies opposite a center roll to the profile to be bent.

In the direction of travel of the profile, at least one support roll is located prior to the shaping roll and if necessary a guide roll opposite the support roll, and there can also be a bending roll behind the shaping roll. In the process, other guide rolls or slides can be provided. A roll bending process can also be accomplished in that a few of the rolls mentioned above are not designed as rolls, but as slides or pressure shoes.

The invention also pertains to not just the bending of profiles in general, but in particular the bending of hollow profiles. Thin-walled hollow profiles present the problem in that the danger exists of collapsing or breaking the profile during bending. In this case, it is preferred that a mandrel shaft be fed inside the profile, said mandrel shaft supporting the profile in the bending zone from the inside.

The invention also pertains to a method to bend and reshape using one or more matrices.

Such matrices are bending tools that consist essentially of slides as described in US 5,884,517, for example. In this case, the problem exists as well of reshaping and/or bending a complicated and thin-walled profile through multidimensional rotation, tilting and shifting of the individual matrices.

All of the bending and reshaping processes mentioned above have been proven in practice. However, problems occur when the profile to be reshaped is hollow with a very thin wall, and when the shaping factor is high. Other problems arise when the material is a very high strength and thin-walled material. Such high strength materials include molybdenum or special alloys with high-strength characteristics that have proven to be especially brittle in the bending and/or reshaping process, thus becoming extremely difficult to bend.

Such high-strength special alloys (among which include not just steel, but also light-metal alloys) cannot be bent using conventional bending methods. Moreover, it has been shown that the material of these kinds of alloys are so brittle during bending and/or reshaping that it breaks, cracks, bubbles or returns to its original state. This means that it can't be bent any longer using conventional means.

This is where the invention comes in, the goal of which is to reshape and/or bend high-strength steel or light-metal alloys that can no longer be bent using conventional methods of the type mentioned above, while nevertheless maintaining good shaping effectiveness with high precision.

To accomplish the object, the invention is characterized by the technical teaching of claim 1.

The essential feature of the invention is that at least one oscillator is assigned to at least one of the bending tools, said oscillator causing the bending tool to oscillate.

Thus, using the teaching indicated, a novel solution approach is proposed in that during roll or matrix bending the respective bending tool used is subjected to an oscillation, wherein at least one of the bending tools is to be so oscillated.

According to the invention, the term “oscillator” is understood to include all suitable oscillators that are capable of causing one or more of the above bending tools (rolls and/or slides and/or pressure shoes and/or matrices) to oscillate, said oscillation consequently being transferred to the bending tool and from there to the profile to be bent and/or reshaped.

Such an oscillator can be an electromagnetic oscillator, for example, wherein a plurality of coil windings is excited by a corresponding excitation current so that the bending tool is caused to oscillate. These oscillations can act on the bending tool both in the longitudinal direction as well as in the radial direction and it is decided from case to case what oscillation is introduced to which bending tool or to which advancing tool.

The invention does not just pertain to the introduction of oscillations to the bending tools but also to the introduction of oscillations to tools that fit inside the profile, such as are provided in particular by means of the mandrel shaft in the longitudinal direction, said mandrel shaft fastened to a mandrel station.

In the process, the mandrel station can itself be excited by the oscillations, as can the mandrel shaft inside the hollow profile (or a tool located inside the profile), which can have its own special oscillator.

Indeed, the article by Eckart Lehfelddt: “Influence of Ultrasound on Internal Friction during Plastic Deformation of Metallic Tools” in VDI-Z-111 No. 6, pages 359-363 (1969) discloses the influence of ultrasound on internal friction in the plastic deformation of metallic materials in general. This document has been confirmed in general with the appearance of such phenomena in the microstructure of metallic materials without reference made to a bending or reshaping process.

However, in the bending and reshaping processes according to the invention that operate using a roll or matrix bending method, a characterizing feature is that the profile to be bent or reshaped is subjected to a flow process that takes place outside and inside the bending zone. Outside the zone, the material of the profile to be reshaped is under tension, whereas in the area opposite to this it is under compression. This results in an rolling effect of the profile to be bent or reshaped since at the same time the microstructure is reformed through volume changes due to the flow process in the microstructure of the profile to be reshaped.

It has now been shown that for high-strength aluminum or steel alloys, this flow process is only insufficient if at least one or more of the bending tools are not caused to oscillate.

This is where the invention comes in with the awareness that concerning the tension or compression process at the profile to be bent, which simultaneously results in a volume change due to the rolling processes, is optimally supported by the production of oscillations.

Tests by the applicant have shown that for the first time it is now possible to easily reshape high strength steels and aluminum alloys (even thin-walled hollow profiles) without cracking or breaking them or causing any undesired deformation of the profile cross section.

Above, it was already explained that any arbitrary oscillator can be used as the oscillator if it is able to achieve the required oscillation frequency. Initially, an electromagnetic oscillator consisting essentially of coils excited with current was cited as the oscillator, through which a middle or high frequency oscillation can flow. Such coils can be excited at an oscillation frequency of 50 Hz to 20 kHz.

In the process, the electromagnetic windings used can be arranged in the longitudinal direction, but electromagnetic windings can also be used that run in the direction perpendicular to it, as well as three-dimensional, current-fed electromagnetic windings that produce longitudinal oscillations as well as oscillations in the radial direction,

wherein even three-dimensional oscillations occur if oscillating electromagnetic coils are used in various directions.

In addition to the oscillators in the form of electromagnetic coils, there is a series of other oscillators that should be included in the technical teaching of the invention. In particular, resonators are considered as ultrasonic oscillators, as well as quartz oscillators and piezo crystals.

In addition to these oscillators, mechanical oscillators are also considered such as eccentric oscillators, hydraulic oscillators or pneumatic oscillators in which the air or fluid cushion produces a corresponding pulsation.

As explained above, the method provides oscillations from 50 Hz to approximately 30 kHz, wherein an oscillation in the area of 16 to 20 kHz is preferred.

In this ultrasound range, especially good results were expected from the oscillation of the bending tools.

With the measures taken according to the invention, an increase in bending effectiveness at profile is accomplished. In the process, either the bending tool itself can be oscillated or a corresponding oscillation can be introduced to the profile to be bent. Both embodiments are encompassed by the concept of the invention.

If only one method to bend hollow profiles were to be shown in the following description, this would not be understood to be limiting. The present method pertains to the bending or reshaping of solid profiles and/or semi-open profiles such as angle, T or double T profiles as well as U profiles.

The object of the present invention not only established from the object of the individual patent claims, but also from the combination of individual patent claims with one another.

All information and features disclosed in the documents, including the abstract, in particular, the spatial design illustrated in the drawings are claimed as essential to the invention to the extent that they are novel in light of the prior art individually or in combination.

In the following, the invention is explained in more detail using multiple drawings depicting possible embodiments. In the process, other features and advantages of the invention derive from the drawings and their description that are essential to the invention.

Shown are:

- Figure 1: a schematic of a bending method according to the invention with the representation of different oscillators at the bending tools,
- Figure 2: a mandrel station to guide a double mandrel shaft, partially shown in section,
- Figure 3: a section through the point of introduction of the double mandrel shaft into the back of the profile to be bent
- Figure 4: a partially modified embodiment of Figure 1 with representation of other details,
- Figure 5: the representation of a chuck with oscillator,
- Figure 6: a different embodiment of Figure 5 with representation of other details,
- Figure 7: a first embodiment of the arrangement of coil windings in a bending roll,
- Figure 8: the rear view of the design according to Figure 7,

Figure 9: a second embodiment of a bending roll,

Figure 10: a third embodiment of a bending roll,

Figure 11: a fourth embodiment of a bending roll,

Figure 12: a fifth embodiment of a bending roll,

Figure 13: a sixth embodiment of a bending roll,

Figure 14: a seventh embodiment of a bending roll,

Figure 15: the rear view of the bending roll according to Figure 14,

Figure 16: a schematic of a reshaping process using matrix reshaping in sectional view

Figure 17: the rear view of the matrix reshaping according to Figure 16,

Figure 18: a side view of the matrix reshaping.

Figure 1 shows a schematic of a profile roll bending machine that consists essentially of a head machine 1 with a center shaping roll 3 inside its frame that acts on the profile 20 to be bent using an initial stress of 400 kN in the direction of arrow 4, for example.

Opposite shaping roll 3 is a center roll 2 that supports the profile 20 from the side.

In the direction of travel behind the shaping roll 3 is an external support roll 6 that sits against the outside of the profile 20 to be bent, whereas an inner guide roll 7 sits opposite support roll 6.

Another bending roll 5 can be placed at the discharge side.

Rolls 5, 6, 7 can also be replaced by corresponding slides with the same effect.

Also shown is that one or more guide rolls 15 are present at the discharge end. These are used to hold the profile to be fed as the profile 20 to be bent is fed in the direction of arrow 62 (see Figure 2).

In the back, the profile is led over a bridge 10, upon which a moveable sled 11 is located. On the sled 11 is a chuck 12 with associated jaws 14 that holds the back end of the profile 20. Two mandrel rods 13 that are parallel to one another extend through the interior of the profile 20, wherein each mandrel rod holds a mandrel shaft 16 at its free front end.

Figures 2 and 3 indicate how the respective mandrel shafts 16 are introduced into the associated profile chamber of the profile 20 and how the profile is pushed over the mandrel shafts.

What is important is that an oscillator is associated with one or more of the bending tools.

In addition, it can also be provided that in addition to the arrangement of oscillators 30 - 37 in the individual bending tools, other oscillators exist that sit against the outside of the profile 20 in the form of slides. Figure 1 shows an embodiment of two vibration saddles 8, 9 opposite to one another that are located between the bending rolls 3, 6 and 2, 7, respectively. These vibration saddles 8, 9 contain their own oscillators that are suitable for exerting corresponding oscillations onto the profile 20 both in the axial direction as well as in the radial direction.

The following description of the individual oscillators is not to be considered limiting. It is only necessary to provide a single oscillator at any of the bending tools on a case by case basis. In other embodiments, however, it is possible that a plurality of bending tools contain such oscillators. Finally, all bending tools cumulatively can be provided with corresponding oscillators.

Figure 1 is shown as an embodiment such that an oscillator 30 is located in chuck 12 that exerts an oscillation onto the profile 20 held there via jaws 14, said oscillation acting in the longitudinal direction.

Furthermore, schematically shown is that in one or more of the bending or support rolls 2, 3, 5, 6 one or more oscillators 31 - 35 are arranged.

Finally, Figure 2 shows that the mandrel station 17, which supports the free, rear end of the mandrel rods 13, is acted upon by an associated oscillator 36. In this way, the mandrel shafts 16 are also caused to oscillate as a result of the mandrel rods 13 that are made to oscillate. More will be said about this later in connection with Figure 4.

Figure 2 shows that the mandrel shaft seat 18 can also be provided with an oscillator that introduces an oscillation that acts on the mandrel shaft in the vertical direction (= Z-plane) in the direction of arrow 19. In this manner, a semi-standing wave is produced in the mandrel rod 13 and thus in the mandrel shafts 16, which results in especially good reshaping results in the interior of the profile. Details are illustrated in this regard in Figure 4.

Here *[in Figure 4]*, it can be seen that the respective mandrel rod 13 has a center hole 22 that runs in the longitudinal direction that leaves space through which to pass the cable and an oil channel. The cable 21 is used to supply the coil winding 23 located inside the mandrel shaft 16 with a pulsating direct current or an alternating current.

Due to the resultant magneto friction and the magnetic effects in the metallic material, the entire mandrel shaft 16 oscillates in the longitudinal direction (direction of arrow 29) and in the perpendicular direction thereto, namely in the direction of arrow 19.

The oil introduced through center hole 22 passes through the mandrel shaft 16 forward in the direction of oil channels 24 that run perpendicular to it and radially outward. There, the oil comes to the outer surface of the mandrel shaft 16 and produces an oil film 25 at the outer surface.

The front side of the mandrel shaft 16 is made up of a head plate 26, the outside surface of which contains opposite casing liners 27 that assume a corresponding support function against the high deformational forces in the bending gap between the shaping roll 3 and the opposite center roll 2.

The high-stress primary bending takes place in the area of the casing liners 27, with a concomitant change in microstructure as described above, wherein the oscillation produced by the coil winding 23 is transferred to the casing liners 27, in particular to the inside of the profile 20.

The vibration production at the mandrel shaft 16 acts furthermore secondarily to minimize the friction between the outer surface of the mandrel shaft and the inner surface of the profile to be bent, in particular in the area of the bending zone.

It has been shown that excellent frictional characteristics have been achieved by the vibration production at the oil film 25, since the oil is especially thin due to the back and forth motion, is distributed well and produces excellent lubrication motion at the inside surface of the profile 20 to be reshaped.

For the purposes of completeness, it should be mentioned that the coil winding 23 is located in a sleeve 28 inside the mandrel shaft 16.

Figure 5 shows that the chuck 12 is also provided with an oscillator 30, wherein the chucking of the profile 20 is done using a chucking cylinder 38 that sits against the outside surface of the profile 20. In the chuck 12 is an oscillator 30 that consists of a current-fed coil winding so that an oscillation is also produced via the chuck 12 in the longitudinal direction. In addition, the figure shows that an oscillator 37 is also associated with the mandrel rod 13. Here, the invention provides in one embodiment that *either* [sic] only the mandrel rod 13 has an oscillator 37, in which case the mandrel shaft 16 has no oscillator.

In another embodiment, however, it can be provided that only the mandrel shaft 16 has the oscillator described previously, whereas the mandrel rod 13 does not have its own oscillator.

Other details are seen in Figure 6.

Here, an oil connection 40 is provided for the introduction of oil to the mandrel rod 13 at the mandrel station 17. Furthermore, the mandrel rod is introduced via guide rolls 39 to the chuck 12 and the oscillator 30 mentioned previously is located in the chuck 12.

Figures 7 through 15 show various embodiments of bending tools that are all provided with an oscillator. Here, it is shown only by way of example that such an oscillator can consist of current-fed coil. The invention is not limited to this, however. Instead of current-fed coil, other oscillators can be used such as had been mentioned in general description portion. In particular, piezoelectric crystals and other oscillators that are capable of producing ultrasonic oscillations are included here.

As a first embodiment, shown in Figures 7 and 8 is that one or more of the bending rolls 2, 3, 5, 6 each are designed as metal rolls, wherein a circular notch 42 is placed at each end of the roll into which the a respective coil winding 44 is inserted. This coil winding 44 is circular as seen in Figure 8.

Such coil windings 44 can be manufactured as self-contained elements by casting them in a plastic body for example, and are then installed as circular elements into each of the associated notches (circular notch 42) at the backs of the respective roll.

In another embodiment, the winding can be inserted directly into the circular notch 42 without having to fix it in self-contained body.

In mass production, it is important that the coil windings 44 can be produced themselves and that they are self-contained so that they can be inserted as a separate element into the

circular notch 42 with a perfect fit at each end of the roll 2, 3, 5, 6. Each end is then closed with a cover 43.

The power supply to the coil windings 44 is done through slip rings that are not shown further and that for example are located at one end of the bending rolls 2, 3, 5, 6 and that are connected to an appropriate power source using associated terminals.

Instead of the wired coupling of the excitation current for the coil windings 44, an inductive (wireless) coupling can also be provided.

The result is that the roll surface 46 oscillates by increasing its diameter, for example forming roll surface 46'.

Also, the roll surfaces can be designed to make a sinusoidal oscillation along their entire axial length so that no radial, outward directed deformation of the roll surface 46 occurs toward roll surface 46, but a sine wave that extends along the axial length of the roll surface 46 and deforms it in the form of a sine curve.

The roll surface 46 is designed between two flanges 21 of enlarged diameter, wherein these flanges can also deform in the manner shown in dashed lines.

The roll 2, 3, 5, 6 is mounted rotatably on the axis 45 by means of a friction bearing.

In addition to a friction bearing, conventional ball bearings or other bearing supports can be used.

Figure 9 shows a dual design of a roll 2, 3, 5, 6 compared to Figure 7, where it can be seen that the roll design is twice that according to Figure 7 and the two rolls about one another near a center joint 47. This leads to the result that the current-fed coil windings 48 exist in especially concentrated form near the joint 47, whereby a very pronounced mechanical deformation is produced in this area. The vibration effect of such a roll 2, 3, 5, 6 is correspondingly increased in comparison to the effect according to Figure 7 and 8.

Another increase results from the design of a roll of this type as a five-part reshaping roll that has a total of six-fold coil windings 48.

Figure 11 shows a fourfold roll according to Figure 9, wherein what is shown additionally is that an additional oscillator can be installed in the axis 45. This oscillator 63 causes an internal excitation of axis 45 with a corresponding oscillation. In the center hole 50 of the axis 45 is a sleeve 51 in which one or more coil windings 52 are located. The coil winding 52 is anchored using a threaded rod 53 and the excitation voltage is introduced via the connection wires 54.

In this way, the entire axis 45 oscillates in the perpendicular direction, namely in the direction of arrow 19, and exerts this oscillation onto the bending tool 2, 3, 5, 6 via the friction bearing mentioned above.

This bending tool (bending roll) then oscillates uniquely due to the separate power supply to the coil windings 44.

In the process, the excitation of the coil winding 52 in the axis oscillator 63 can be produced at another amplitude and another oscillation frequency such as the excitation of coil windings 44.

This guarantees that the bending roll 2, 3, 5, 6 oscillates both in the longitudinal direction as well as in the radial direction 19.

Figure 12 shows another oscillator 55 placed on the axis 45 instead of an oscillator 63 located internal to the axis. This oscillation package consists essentially of an external coil winding 56 that is located in an associated support that is placed on the axis 45 as tightly as possible. In this way, the axis 45 experiences an oscillation in the longitudinal direction and in the perpendicular direction. This oscillation is conveyed to roll 2, 3, 5, 6 as well via the associated friction bearing.

Figure 13 shows in another embodiment that the coil windings 58 are located near a bushing 57 that forms a friction bearing with the axis 45 as a special part. The bushing 57 is therefore easily replaced and can be replaced by other bushings with other coil windings 58.

It supports a center support ring 29 of enlarged diameter through which the bending forces are absorbed, said forces acting in particular on the middle range of the roll 2, 3, 5, 6.

Figures 14 and 15 show in another embodiment that roll 2, 3, 5, 6 can also have axial holes 60 that are distributed along the periphery and that sit parallel to one another, wherein a coil winding 61 fits in each axial hole and wherein all coil windings 61 are fed by a common power source. Here as well, the two ends are likewise covered by a single cover 43.

Figure 16 - 18 shows in general a reshaping process that uses known matrix reshaping methods. In the process, a bending matrix 70 is provided in two or three spatial axes. This matrix can be moved in the directions of arrows 71, 72, 75 and in addition can be rotated in the rotational directions 73, 74.

The profile 20 to be bent extends through the passage gap of the bending matrix 70. A mandrel shaft 16 is led inside this profile (as shown above) in the bending zone, said shaft moved by a mandrel rod 13.

One or more fixed matrices 64 are located at a distance from the bending matrix 70 that sit against the profile to be bent and that have lubricating pad 67 at these seat surfaces.

What is important at this point is that at least one oscillator 65 is assigned to the bending matrix 70, said oscillator producing an approximately centric (star-shaped) oscillation at the passage gap in the bending matrix 70 so that it rhythmically enlarges and reduces and thus communicates a corresponding vibration to the profile 20 to be bent.

In addition, the fixed matrices 64 can be assigned their own oscillators 66. These oscillators act on the lubricating pad 67 in particular, which as a result are caused to oscillate in order to produce an improved lubrication effect on the profile 20 being fed through at that point.

The profile to be bent is fed through in the direction of arrow 68 through the fixed matrices 64 and the bending matrix 70 that follows.

It is obvious that the mandrel rod 13 and/or the mandrel shaft 16 can be acted upon by its own oscillator as was explained above in the general description.

Likewise, it is possible to impart the profile itself with an oscillation via the chuck 12.

Also, in this exemplary embodiment according to Figures 16 - 18, the lubrication in the mandrel shaft 16 can occur with the aid of an oscillator as was explained in Figure 4.

All discussions concerning the roll bending method therefore apply to the matrix bending process according to Figures 16 - 18.

Drawing Legend

1	Head machine	30	Oscillator
2	Center roll		(Chuck
3.	Shaping roll	31	"
4	Arrow direction	32	"
5	Bending roll	33	"
6	Support roll		(Shaping roll)
7	Guide roll	34	"
8	Vibration saddle		(Center roll)
9	Vibration saddle	35	"
10	Bridge	36	"
11	Sled		(Mandrel station)
12	Chuck	37	"
13	Mandrel rod		(Mandrel station)
14	Support mesh	38	Chucking cylinder
15	Guide roll	39	Guide roll
16	Mandrel shaft	40	Oil connection
17	Mandrel station	41	Flange
18	Mandrel shaft seat	42	Circular notch
19	Arrow direction	43	Cover
20	Profile	44	Coil winding
21	Cable	45	Axis
22	Hole	46	Roll surface 46'
23	Coil winding	47	Joint
24	Oil channel	48	Coil winding
25	Oil film	49	Friction bearing
26	Head plate	50	Center hole
27	Casing liner	51	Sleeve
28	Sleeve	52	Coil winding
29	Arrow direction	53	Threaded rod
		54	Connection wire

55	Oscillator	66	Oscillator
56	Coil winding	67	Lubricating pad
57	Bushing	68	Arrow direction
58	Coil winding	69	
59	Support ring	70	Bending matrix
60	Axial hole	71	Arrow direction
61	Coil winding	72	Arrow direction
62	Arrow direction	73	Direction of rotation
63	Oscillator	74	Direction of rotation
64	Fixed matrix	75	Arrow direction
65	Oscillator		